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Some Results of the First Year of Participation of the Svetloe Observatory in IVS Observing Programs

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Abstract

Results of the first 16 geodetic VLBI sessions observed in 2003 at the Svetloe Radio Astronomical Observatory (SvRAO) of the Institute of Applied Astronomy (IAA) in the framework of the IVS observing programs are presented. Analysis of observations has been performed at the IAA using OCCAM/GROSS software. The processing of the observations allowed us to determine with high accuracy both the coordinates of the SvRAO and Earth orientation parameters. It is also shown that inclusion Svetloe observatory in the IVS network yields essential improvement of the accuracy of determination of the EOP. Obtained results show high quality of both observations and analysis made at the IAA.

1. Introduction

Svetloe Radio Astronomical Observatory (SvRAO) was founded by the Institute of Applied Astronomy (IAA) of the Russian Academy of Sciences (RAS) as the first station of the Russian VLBI network QUASAR. It is located in the Karelian Neck about 100 km towards North of St.Petersburg, and is primarily intended for regular observations in the framework of domestic and international VLBI programs [1, 2].

Until the end of 2002 SvRAO was equipped with only one terminal, Canadian S2, with Data Acquisition System developed at the IAA. Using this terminal, SvRAO participated in a number of VLBI programs in collaboration with other VLBI stations in China, Canada and Australia, also with the second IAA VLBI station, Zelenchukskaya, located in the North Caucasus.

In 2002, according to the Agreement between the RAS and NASA, a Mark IIIA terminal was installed at SvRAO, and since March 2003 the SvRAO started regular VLBI observations in the framework of the IVS astrometry and geodynamics programs. Being a result of nearly 15 years of efforts by the IAA, this is a major milestone for us.

2. VLBI Equipment of the SvRAO

The basic instrument of the SvRAO is a new generation fully steerable radio telescope with homology backup structure. The quasi-paraboloid main dish has a diameter of 32 m and focal length of 11.4 m, and the secondary mirror is an asymmetrical modified hyperboloid with diameter of 4 m. To be able to switch frequency band and provide multi-band observations quasi simultaneously, the input horns for different wavelengths are located above the circle of 3-meter diameter and fast switching is achieved by turning of the secondary mirror at certain angle around the radio telescope axis. To maintain simultaneous receiving at S and X bands in both orthogonal polarizations (to eliminate ionosphere effects), which is essential for realization of astrometric, geodynamical and geodetic programs, a special combined horn has been constructed.

The radio telescope is equipped with 5 low-noise cooled receivers with HEMT amplifiers for wavelengths 1.35, 3.5, 6.0, 13 and 18/21 cm for observations in the left and right circular polarizations. Micro-cryogenic closed circle refrigerators are used for the cooling of low noise amplifiers at 20 K. The working ranges of intermediate frequencies of the cryo electronic radiometers are 130–480 MHz and 130–890 MHz for X and S bands correspondingly. The noise temperature at the input of the cryostat is 15 K, and the total noise system temperatures are not higher than 50 K for S band and 70 K for X band at elevations above 20°. The signal from the radiometers is transmitted along phase stable coaxial lines connecting the focal cabin of the radio telescope with the Mark IIIA and S2 terminals located at the laboratory building.

The Svetloe VLBI site is provided with a qualitative system of time-frequency synchronization, consisting of 4 H-masers with long-time stability about $(3-5)\times 10^{-15}$. One H-maser operates constantly and each other can be switched on during one hour and will achieve all nominal technical parameters during 24 hours. The synchronization of the local time scale with Universal Time is realized with the use of GPS and GLONASS receivers with accuracy (30–50) ns.

The phase calibration system — generator of picosecond impulses includes two basic units: pulse generator of harmonics on semiconductor diode and circuit producing 1 MHz reference signal with rectangular wavefront from the harmonic signal with the frequency of 5 MHz provided by the H-maser. The measurement of the delay of 5 MHz reference signal in cable system is provided by phase comparator.

An automatic meteorological data system measures atmospheric pressure, direction and velocity of wind, temperature and humidity of air. These data are recorded in log-file of the media.

All systems of the radio telescope are united in general complex with the help of central computer with specialized software, permitting the automatic carrying out of observations in both VLBI and single dish modes. The basis of this software is the Mark IV Field System, v. 9.5.17. It was added by site-oriented interface developed at the IAA for control of the antenna, radiometers and registration terminals.

3. Observations and Results

The first regular IVS session at Svetloe was observed on March 6, 2003 [3]. In 2003 Svetloe participated in 21 IVS sessions — 16 R4 sessions (determination of EOP), 3 TRF sessions (improvement of the terrestrial reference frame), 2 EURO session (investigation of crustal deformations in Europe). Five R4 sessions (R4079, R4081, R4083, R4085, R4089) were correlated without Svetloe because of delay in tape delivering due to customs problems. In November 2003 Mark III BBC were transported to the USA for upgrade, and for this reason IVS sessions scheduled for the end of 2003 — the beginning of the 2004 were canceled. List of sessions observed at SvRAO in 2003 and related statistics are presented in Table 1.

During those 16 IVS sessions observed with the participation of SvRAO 33194 observations were obtained, 29197 of them are suitable for a scientific analysis. These observations were obtained at 22 VLBI stations, and 116 baselines of length from 99 km (DSS65–YEBES) to 12,496 km (DSS45–YEBES). Station statistics is presented in Table 2.

Scientific analysis of the observations has been performed at the IAA using OCCAM/GROSS software, and was primarily aimed to compute accurate coordinates of Svetloe radio telescope

Table 1. VLBI sessions observed at Svetloe in March–November 2003.

Session code	Date	Number of stations	Number of sources	Number of scans	Number of observations
R4061	MAR 06	8	36	313	2373
T2015	MAR 18	7	44	348	2079
R4063	MAR 20	8	34	332	2902
R4065	APR 03	8	44	322	2305
T2016	APR 08	7	38	231	1067
R4069	APR 29	8	47	340	2693
EURO68	MAY 06	9	53	324	5433
T2017	MAY 20	8	54	542	1985
R4073	MAY 29	8	54	399	2306
R4075	JUN 12	5	43	203	658
R4087	SEP 04	8	54	336	2322
EURO69	SEP 23	5	42	294	1807
R4091	OCT 02	6	46	279	1084
R4093	OCT 16	6	48	280	1065
R4095	OCT 30	7	48	256	1468
R4097	NOV 13	7	49	268	1647
Total		22	98	5067	33194

reference point and the EOP. Geocentric coordinates of the Svetloe radio telescope reference point obtained at the IAA are presented in Table 3.

For this computation coordinates of all stations except Svetloe were fixed to VTRF2003 values except coordinates of Gilmore Creek which was corrected for the jump in station position due to the earthquake that happened in November 2002. For comparison, VTRF2003 values, estimate obtained at the Main Astronomical Observatory (MAO), Ukraine (mao2003a.trf), and the latest GSFC estimate kindly provided by Daniel MacMillan (personal communication) are also included in the Table. All the solutions were obtained from processing of 10–11 observing sessions, except VTRF which is based only on one observing session R4061.

It is important that as a result of the IVS experiments Svetloe is now tied to 21 other globally distributed VLBI stations (Fig. 1). Estimates of the the baseline lengths including Svetloe are presented in Table 4.

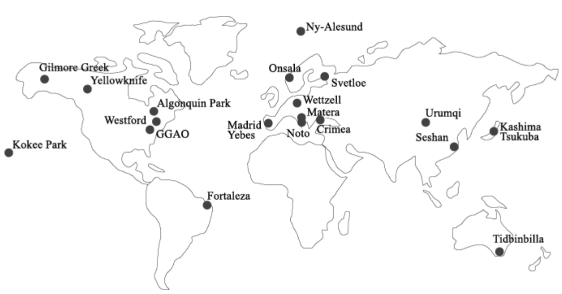

Figure 1. Stations observed along with Svetloe.

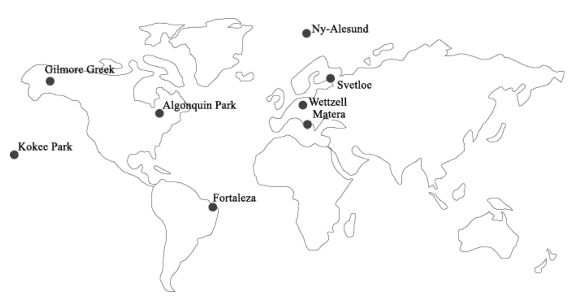

Figure 2. Typical IVS R4 network in 2003.

Table 2. List of participating stations (D – distance from Svetloe, Nsess –number of sessions, Nobs – number of observations, Ngood – number of good observations, Nav – average number of good observations per session, Pg – percentage of good observations).

Station	Location	D	Nsess	Nobs	Ngood	Nav	Pg
ALGOPARK	Canada	6256	11	5784	5270	479	91.1
CRIMEA	Ukraine	1811	3	968	779	260	80.5
DSS45	Australia	11734	1	505	401	401	79.4
DSS65	Spain	3192	2	1725	1589	794	92.1
FORTLEZA	Brazil	8428	12	3809	3378	282	88.7
GGAO7108	USA	6767	2	91	47	24	51.6
GILCREEK	USA, Alaska	5854	6	4340	4113	686	94.8
KASHIM34	Japan	7174	1	608	513	513	84.4
KOKEE	USA, Hawaii	9561	11	4227	3797	345	89.8
MATERA	Italy	2374	12	8061	6581	548	81.6
MEDICINA	Italy	2140	2	2069	1771	886	85.6
NOTO	Italy	2809	1	1420	1227	1227	86.4
NYALES20	Norway, Spitsbergen	2133	11	8244	7511	683	91.1
ONSALA60	Sweden	1080	3	2690	2348	783	87.3
SESHAN25	China	6761	1	569	492	492	86.5
SVETLOE	Russia	—	16	8386	7369	461	87.9
TSUKUB32	Japan	7141	2	1321	1165	582	88.2
URUMQI	China	4127	2	1116	823	412	73.7
WESTFORD	USA	6269	1	283	204	204	72.1
WETTZELL	Germany	1655	13	8541	7720	594	90.4
YEBES	Spain	3130	2	1427	1100	550	77.1
YLOW7296	Canada	5807	1	204	196	196	96.1

Table 3. Svetloe coordinates at the epoch 2003.30 aligned to ITRF2000.

Analysis center	X, m	Y, m	Z, m
IAA	2730173.850 ±0.001	1562442.667 ±0.001	5529969.064 ±0.002
GSFC	.849 ±0.001	.666 ±0.001	.063 ±0.002
MAO	.838 ±0.002	.670 ±0.001	.070 ±0.003
VTRF	.850 ±0.003	.668 ±0.002	.071 ±0.006

It should be mentioned that in 2003 station Svetloe was included in the IVS network as tagged along station. i.e supplementary to the regular IVS R4 network. Figure 2 shows a typical configuration of the R4 network in 2003. One can see that Svetloe is located near other European stations, and thus does not strengthen substantially the network geometry. Nevertheless, we tried to estimate how it influences the accuracy of EOP results (the main goal of the IVS R4 program). Estimates of pole coordinates X_p, Y_p, $UT1$, and celestial pole offset X_c, Y_c were computed for each session both for whole network and for reduced network without Svetloe. Summary statistics for IVS R4 sessions is presented in Table 5.

Table 4. Baseline lengths from Svetloe to other stations (N — number of sessions).

Station	N	Length, m	Station	N	Length, m
ALGOPARK	11	6255567.6375 ± 0.0017	NOTO	1	2808545.4758 ± 0.0031
CRIMEA	2	1810877.6191 ± 0.0035	NYALES20	11	2133122.9974 ± 0.0008
DSS45	1	11734020.5515 ± 0.0170	ONSALA60	3	1079812.9398 ± 0.0012
DSS65	2	3192391.5692 ± 0.0022	SESHAN25	1	6760938.2664 ± 0.0104
FORTLEZA	12	8428008.6828 ± 0.0026	TSUKUB32	2	7140832.1567 ± 0.0042
GGAO7108	1	6767247.5683 ± 0.1347	URUMQI	2	4127151.1143 ± 0.0043
GILCREEK	6	5853689.1331 ± 0.0019	WESTFORD	1	6269171.0924 ± 0.0137
KASHIM34	1	7173755.4892 ± 0.0111	WETTZELL	13	1654774.8551 ± 0.0007
KOKEE	10	9561115.4073 ± 0.0029	YEBES	2	3129769.6030 ± 0.0043
MATERA	12	2373640.0972 ± 0.0009	YLOW7296	1	5807450.7281 ± 0.0165
MEDICINA	2	2139526.9604 ± 0.0024			

Table 5. EOP uncertainty (X_p, Y_p — pole coordinates, μas, $UT1$ — Universal Time, μs, X_c, Y_c — celestial pole offset, μas), and related statistics (σ_0 — post-fit rms, ps, C_{max} — maximum correlation between EOP) for IVS R4 sessions.

Network	$\sigma(X_p)$	$\sigma(Y_p)$	$\sigma(UT1)$	$\sigma(X_c)$	$\sigma(Y_c)$	σ_0	C_{max}
All stations	103	75	35	56	58	0.697	35
w/o Svetloe	113	79	41	58	61	0.730	37

Obtained results show that including Svetloe in the IVS network yields clear improvement in the quality of results. Hopefully, further participation of SvRAO in IVS programs as a regular station will allow us to realize more substantial progress in the accuracy of determination of EOP and TRF, and make a valuable contribution to geodesy and astrometry studies.

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